# Great Lakes Ice Cover Mapping with RADARSAT-2 SAR Data


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## Abstract

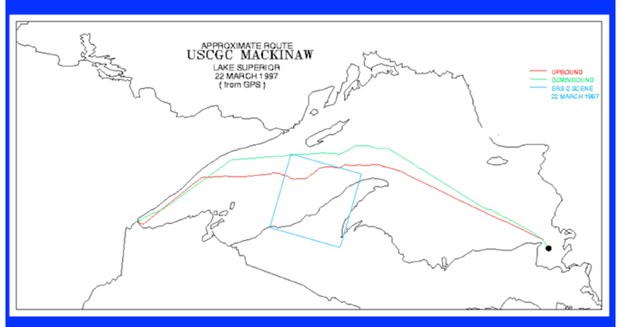
The objectives of this project are to use RADARSAT-2 data to continue the development of advanced algorithms to classify and map ice cover on the Laurentian Great Lakes started using synthetic aperture radar (SAR) data from ERS-1, ERS-2, and RADARSAT-1. NASA JPL and NOAA GLERL, together with support from the US Coast Guard, have carried out field experiments on the Great Lakes that have resulted in a comprehensive C-band fully polarimetric backscatter signature data set up to 60 degrees incidence angles for various ice types together with "ground truth" data. This unique data set is directly applicable to RADARSAT-2 data (same frequency, all polarizations, and incidence angles) to continue development using its dual polarimetric and fully polarimetric (Quad-Pol) capabilities. Since imagery was not available during winter 2007-08, RADARSAT-2 Quad-Pol data was obtained over western Lake Superior during GLAWEX09 (Great Lakes Winter Experiment 2008-09) coincident with data collection from the icebreaker USCGC Alder. One of the main goals of the experiment was to determine if multi-polarization data can be used to identify ice and open water without the ambiguity that can be caused by variability in wind speed and direction over water using single polarization, single frequency data (Leshkevich and Nghiem, 2007). Providing greater discrimination and less ambiguity than single band, single polarization data, dual polarization and Quad-Pol data at large incidence angles may improve ice type discrimination and mapping that are robust over a wide range of wind speed and direction. At small incidence angles and with a single polarization, RADARSAT-2 results show that ice and water can be discriminated over Lake Superior. After identifying ice and open water, our polarimetric library of C-band backscatter signatures of different freshwater ice types (Nghiem and Leshkevich, 2007) was applied to the imagery to classify and color-code the ice types. Once fully developed, this algorithm can be used in an automated procedure to obtain ice concentration, ice type, and ice mapping of importance to operational ice breaking and winter navigation as well as winter ecology, fisheries recruitment, and ice cover modeling efforts.


### Great LAkes Winter Experiment (GLAWEX97)

JPL C-band Scatterometer used to collect library of polarimetric backscatter signatures (0-60° incident angle) from different ice types on Lake Superior from USCG icebreaker.

### USCGC Mackinaw in Whitefish Bay, Lake Superior

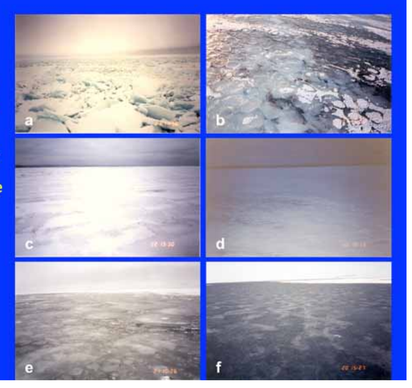

### Route of USCGC Mackinaw Across Lake Superior during GLAWEX97




Box Represents Coverage of ERS-2 SAR Scene, March 22, 1997

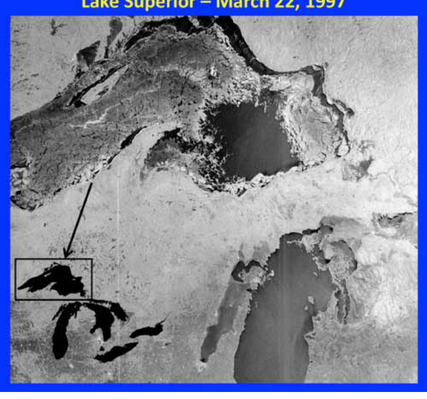
### Major Ice Types Measured During GLAWEX97

(a) Brash ice
(b) Pancake ice
(c) Patchy snow cover on snow ice over lake ice
(d) Lake ice with patchy and rough snow cover
(e) Rough consolidated ice floes
(f) New lake (Black) ice

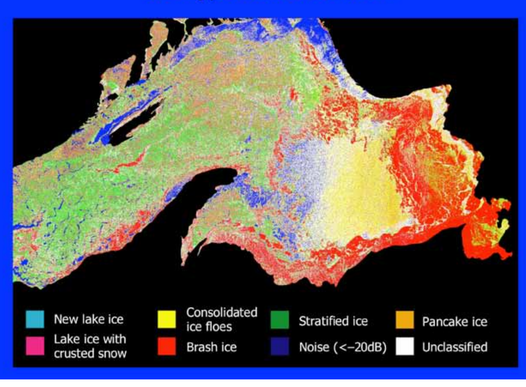



### RADARSAT-1 Image (C-HH)

Lake Superior – March 22, 1997

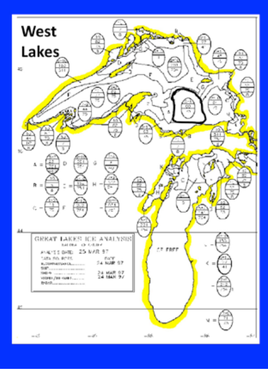


### RADARSAT-1 March 22, 1997 Ice Type Classification



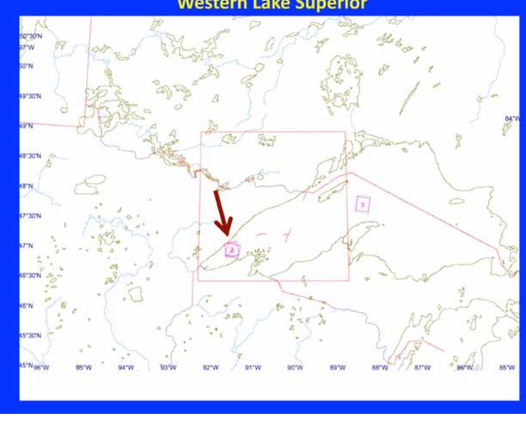

### Verification with NIC Ice Charts

Ice Charts from National Ice Center




In this RADARSAT-1 single band, single polarization image, open water was misclassified as Consolidated Ice Floes owing to variations in wind speed and direction over water.

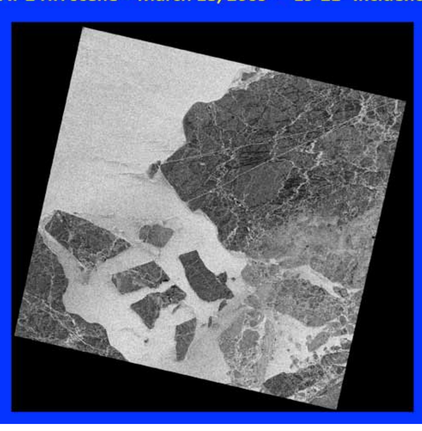
### RADARSAT-2 Quad-Pol Scenes – March 18, 2009 – Western Lake Superior



### MODIS Aqua True Color Image of Lake Superior – March 18, 2009

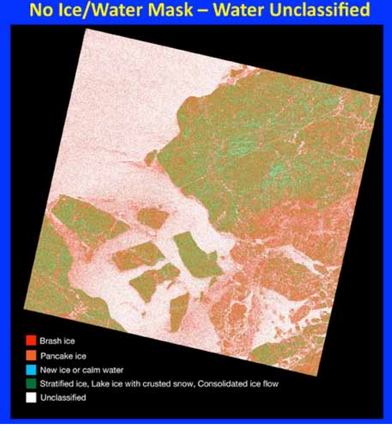
No Ice/Water Mask – Water Unclassified

### RADARSAT-2 HH scene – March 18, 2009 - ~19-21° Incidence Angle

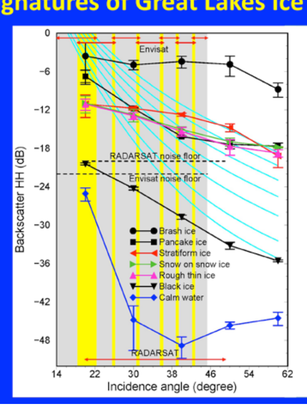


### Ice Classification RADARSAT-2 HH Lake Superior March 18, 2009

No Ice/Water Mask – Water Unclassified

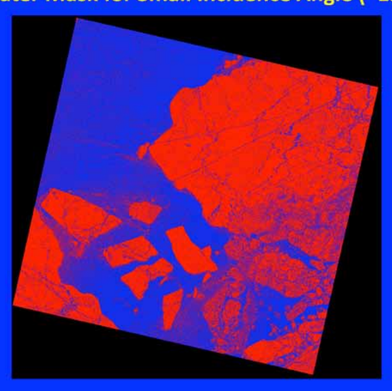



### Horizontal-polarization Backscatter Signatures of Great Lakes Ice Types and Calm Water

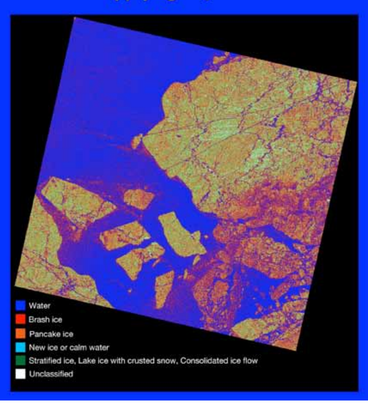



The family of cyan curves represents model values of horizontal-polarization backscatter of ice-free water for neutral wind speeds of 2 $ms^{-1}$ and 4 $ms^{-1}$ to 24 $ms^{-1}$ in increments of 4 $ms^{-1}$ (lower to upper cyan curves).

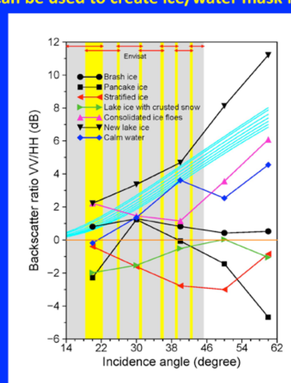
### Ice/Water Mask for Small Incidence Angle (~19 – 21°)



### Ice Classification RADARSAT-2 HH Lake Superior March 18, 2009 after applying Ice/Water Mask




### Co-polarized Backscatter Ratios of Great Lakes Ice and Calm Water can be used to create ice/water mask for large incidence angle imagery




The family of cyan curves represents model values of co-polarization backscatter of ice-free water for neutral wind speeds of 2 $ms^{-1}$ and 4 $ms^{-1}$ to 24 $ms^{-1}$ in increments of 4 $ms^{-1}$ (upper to lower cyan curves).

### Conclusions

- Can classify different ice types in an ice cover using C-band SAR data.
- Water can be misclassified as ice in single band, single polarization data owing to wind speed and direction.
- Can separate ice and water in low incidence angle imagery by using spectral mask.
- Should be able to separate ice and water in high incidence angle imagery by using HH/VV ratio.

## REFERENCES


Leshkevich, G.A. and Son V. Nghiem, 2007. Satellite SAR Remote Sensing of Great Lakes Ice Cover Part 2. Ice Classification and Mapping. *Journal of Great Lakes Research*, 33(4):736-750.

Nghiem, S.V. and G.A. Leshkevich, 2007. Satellite SAR Remote Sensing of Great Lakes Ice Cover, Part 1. Ice Backscatter Signatures at C-Band. *Journal of Great Lakes Research*, 33(4):722-735.